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0.1	20/9/02	Initial document formed	Note that this document has, in part, been generated from sections of the old Science Requirements document (which dealt with early ideas of the operational concepts discussed here).
0.2	3/10/02	All sections	Revised version prior to comments
1.1	6/10/02	Mainly sections 5.2 and 6.	Comments received and included

Reference documents

Reference	Document title	Document number	Issue	Date
SC	SCUBA-2 Science Case	SC2/SCI/01	1.2	5/5/01
SRE	Science requirements	SC2/SRE/SC200/01	1.2	6/10/02
FPRD	Functional and performance requirements	SC2/SRE/SC200/02	1.5	6/10/02
BDK19	SCUBA-2 and the JCMT secondary mirror	SC2/ANA/S100/39	1.0	27/5/02
BDK23	The SCUBA-2 flat-field problem	SC2/ANA/S100/43	1.0	3/10/02
HVSG1	DREAM observing with SCUBA-2	SC2/ANA/S100/46	1.0	6/10/02
SUN216	SURF: SCUBA User Reduction Facility	Starlink User Note 216.7	1.6	6/7/00
SUN230	ORAC-DR: Overview and general introduction	Starlink User Note 230.3	3.0-0	30/11/01
SUN231	ORAC-DR - SCUBA pipeline data reduction	Starlink User Note 231.3	2.1-0	1/4/01
JOT	The JCMT O-T primer		–	1/10/02
OMP	The JAC Observation Management Project Requirements	OMP/PN/006	–	5/01

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Operational Concepts Definition for SCUBA-2

This document describes the operational concepts required for SCUBA-2.

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1. Introduction

This document describes the concepts for SCUBA-2 operation at the telescope for allocated observing projects.

It is envisaged that SCUBA-2 will provide JCMT with the following observing modes:

- **Imaging mode**: observing regions of sky equivalent to the array field-of-view or mosaicing together offset frames to produce an image up to a few arrays in size
- **Survey (or scan) mode**: mapping large areas of sky, potentially up to tens of degrees at a time
- **Spectroscopic/polarimetric mode**: Imaging polarimetry and medium resolution spectroscopy will be possible with additional hardware (an additional Canadian CFI contribution)

Operationally, it is likely to differ from previous JCMT instruments in that it must be capable not only of *'normal' observing programmes* (scheduled as blocks of between a few hours and several shifts), but also for conducting large-area *'semi-automated' surveys* of the sky (perhaps carried out by one person remotely from Hale Pohaku or Hilo). In particular, the latter mode requires well thought out observing strategies and data reduction pipelines, as well as a stable and reliable instrument.

The biggest contribution that SCUBA-2 will make to submillimetre astronomy is in surveying large areas of sky to great depth. *SCUBA-2 will therefore seek to maximise survey speed*. This is defined as the speed with which areas of sky can be surveyed to a given depth. It is inversely proportional to the time taken to image to that depth:

Survey speed ∝ (area to be mapped) / (time taken to reach a given depth in a single frame)

The issues of pixel scale (sampling) and sensitivity are closely related to the survey speed. This document describes the operation concept i.e. how SCUBA-2 will be operated and how the various interactions will be managed. These include all aspects of the "observing process" from defining SCUBA-2 programmes and submitting them, to acquiring data and maintaining close quality control on the output product.

2. Top-level system

Figure 1 is a representation of how we envisage the SCUBA-2 top-level information flow to be. This goes from Science Definition, through the programme submission and selection phase, to the acquisition of the data, and finally the data analysis, pipeline processing and archiving.

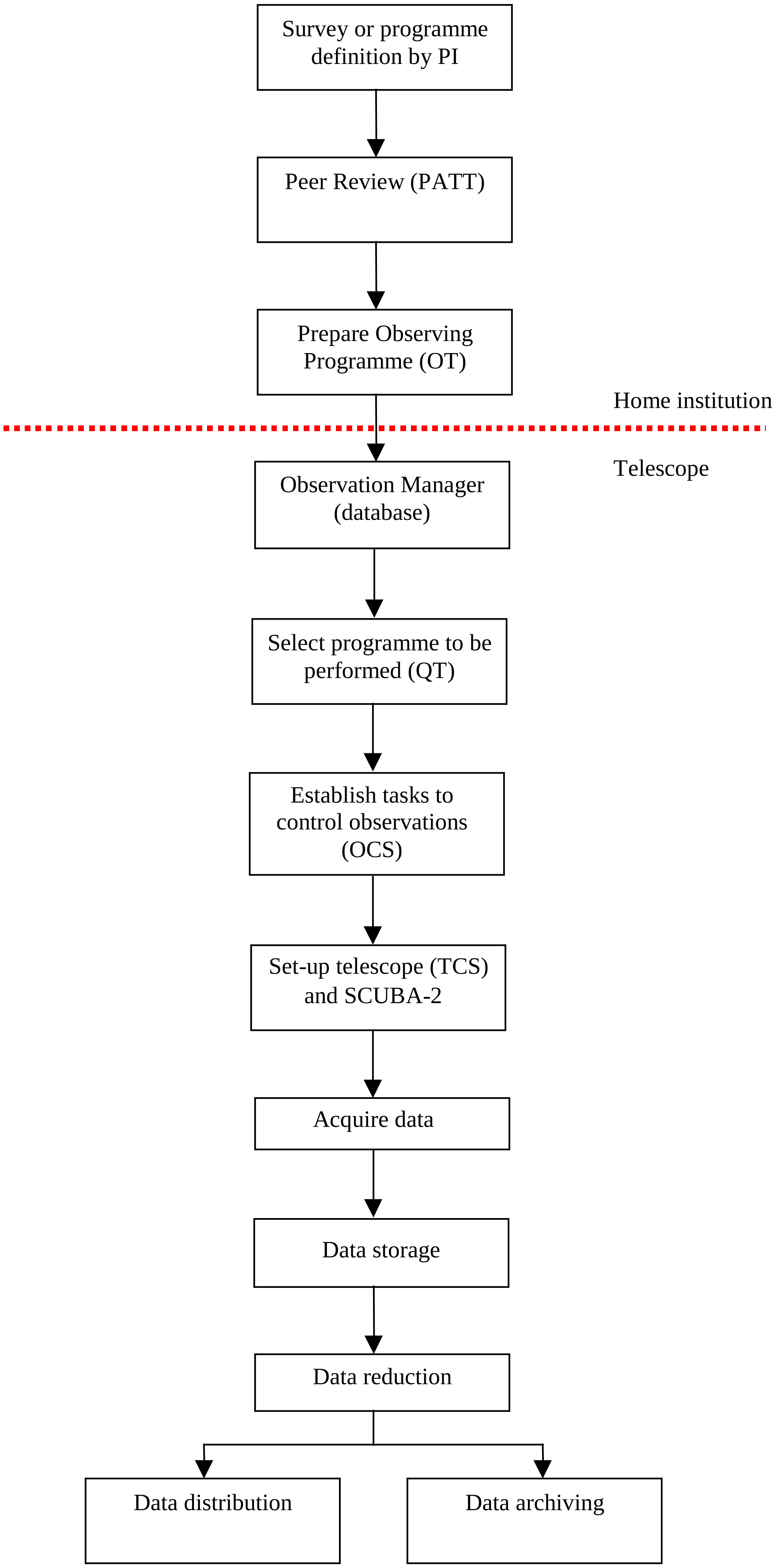

Figure 1: SCUBA-2 top-level information flow

3. Observing programme definition

At top-level to define a SCUBA-2 observing programme the following will be required:

- Programme definition (source list etc)
- Observing recipes (standard or user customised)
- Pipeline (data reduction) recipes

The observing programme will be defined using a modified version of the JCMT Observing Tool (OT). It is anticipated that such programmes will incorporate the Minimum Schedulable Block (MSB) concept recently introduced at the JCMT. In this, a MSB is simply a sequence of observations (on a programme source, as well as calibrations) which are scheduled as a single item. The OT will call upon a set of instrument configurations or *observing recipes* which will have been defined by the SCUBA-2 Project Team. These recipes will define the "control" of the observation. At top-level they will be in the form of either an *Imaging Definition (ID)* or a *Survey Definition (SD)*, and will be capable of being customised by the user. For the purposes of this document we do not consider the polarimetric and spectrometer options, since these are considerably less well defined at time of writing.

3.1 Imaging definition

Deep imaging of single (or a few mosaiced) fields, perhaps as deep as to get to the confusion limit, will be the simplest observation to define.

To be defined for this mode:

- RA/dec for the telescope pointing (as well as offsets, as appropriate)
- The micro-step pattern
- The observing pattern (STARE or DREAM)
- Integration time per "exposure"
- Quality control parameters for the observation (see section 8)
- Calibration observations

In this case an "exposure" is defined as a series of frames before another operation (e.g. dark frame, pointing, calibration) is performed. A frame is one complete read out of the SCUBA-2 arrays.

3.2 Survey definition

It is likely that SCUBA-2 will conduct a number of "legacy-style" surveys, similar to the planned UKIDSS for WFCAM, although this has not been formally discussed at this stage. However, it is certain that such surveys will be an important part of SCUBA-2 operation at the telescope.

To be defined for this mode:

- RA/dec for the telescope pointing (as well as offsets, as appropriate)
- The scan angle
- The length of the scan
- Scanning speed (which will define the integration time per spatial point)
- The overlap of scans (if appropriate)
- Quality control parameters for the observation (section 8)

- Calibration observations

4. Observing programme management and execution

After successful peer review, the complete observation definition is sent (usually by the programme PI) to the JAC to be incorporated into the Observation Management System (OMP). The observing programme management is entirely the responsibility of the staff at the JAC. The OMP effectively organises the scheduling of the observation according to criteria such as scientific priority, source availability, and observing conditions. The observations are stored in a database and queried at the telescope by the Query Tool (as shown in Figure 1).

The observation, once selected, then passes to the "Observation Driver", which is part of the Observatory Control System (see Figure 2).

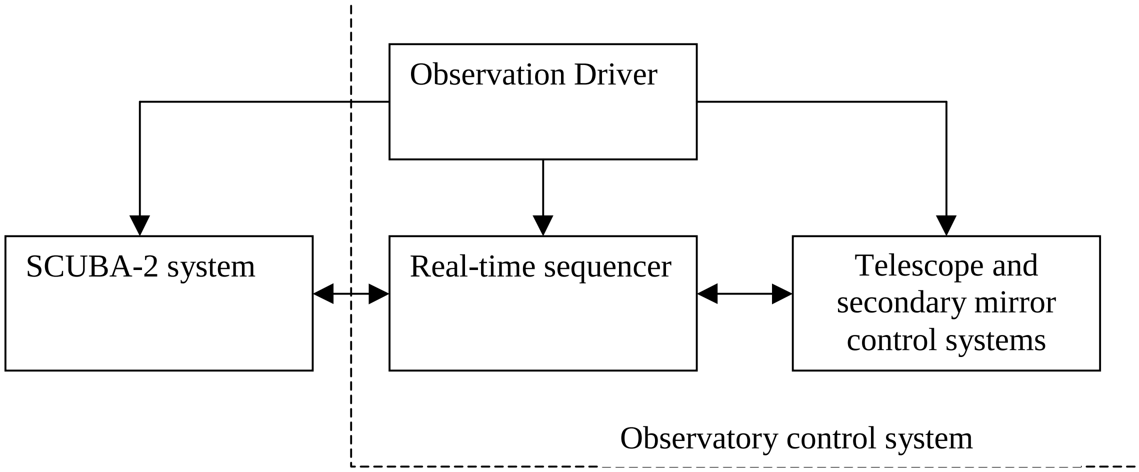

Figure 2: Observation execution control steps

The Observation Driver carries out the observations by setting up the SCUBA-2 system, RTS and telescope system, before handing over control to the RTS that will co-ordinate the data taking with the relevant hardware signals.

5. Observing modes

5.1 Requirements

A basic set of observing strategies has been defined from a consideration of the science requirements. The Science Requirements (SRE) document discusses the observational limits (integration times and map sizes) and the types of observation astronomers are likely to want to take. In this section we start to discuss practical implementations of these requirements.

It is important to remember that SCUBA-2 will operate in a fundamentally different way to SCUBA. SCUBA-2 is likely to have a significant advantage over the current SCUBA in that the detectors are DC rather than AC coupled. The current system requires dual beam chopping which removes the sky and the DC level in the map and has zeroes in the response in the spatial frequency domain. This means that map reconstruction has the potential to introduce artefacts into the data. This can significantly compromise performance, particularly with sources near the confusion limit.

However, as in the case of SCUBA, the single most important factor, which will govern the quality of data, is the atmosphere. The sky is not stable due to the dominance of water vapour in determining the atmospheric transmission. Furthermore, the fact that water is poorly mixed in the atmosphere means that water concentrations vary both temporally and spatially generating "sky noise" and "seeing" effects. This means that we have to find ways of dealing with problems due to variations in atmospheric transmission, sky-noise and refraction ("seeing") effects.

In addition, the SCUBA-2 observing strategies have to cope with:

- bad pixels or columns of pixels
- the approximate one pixel gap between the 4 sub-arrays
- field distortion (although this is predicted to be much lower than SCUBA)
- field rotation (Alt/Az telescope with no field rotator)
- 1/f noise in detectors and electronics
- obtaining highly accurate and stable flat fields (due to high background power per pixel)

Since the detectors will be DC coupled this means that the array can, in principle, simply stare at the sky in a way akin to a CCD or IR camera. Sky chopping in the conventional sense is not required and hence there is the potential to adopt some of the observing techniques used in the infrared. This will lead to significant efficiency improvements, since half of the integration cycle is not spent on blank sky. Better image fidelity, sensitivity to source structure on ALL scales should also be achievable. It also gives a lower confusion limit i.e. by not continuously subtracting two images of the sky. However, the main complication is that 1/f noise from detectors or electronics must be at an acceptable level.

5.2 Basic observing modes

Table 1 summarises the basic observing and calibration modes identified in the SR document. There are described in considerably more details in separate documents.

Mode	Modulation	Dealing with bad pixels/inter-array gaps	Dealing with $F\lambda$ pixels at 450μm	Flat fielding accuracy required	Limitations and requirement
STARE	Assume sky and telescope background has simple structure i.e. fit a plane to the data using knowledge of the flat field.	Micro-step with SMU	Micro-step with SMU	High Q. Can we achieve flat-field accuracy required?	Needs dark shutter, pixel heater and way of obtaining flat field over range of input powers. Needs low 1/f from system so that dark shutter does not have to be deployed too often
DREAM	SMU in DREAM patterns	Algorithm for bad pixels/columns and sub array gaps	Micro-step with SMU as part of DREAM sequence (over-sample at 850μm).	Low	Noise propagation and computer power. Dark shutter not essential, but use of it plus heater control to track relative responses.
SCAN	Constant velocity of telescope	Overlap of pixels (and scans)	Choose appropriate scan directions	Low	Needs low 1/f?
SKYDIP	Move telescope to a variety of elevations. Average gradient across array can also give τ.	N/A	N/A	Can measure flat-field as a function of relative background – fit same τ to each pixel	Probably can not slew telescope continuously because of need to servo pixel heater power
FLAT-FIELD	Stare at a constant temperature source (positioned at a pupil image)	N/A	N/A	N/A	Long integrations probably necessary (daytime?)

Table 1: Summary of observing and calibration modes for SCUBA-2

A requirement for any instrument that will perform *deep imaging* is that the rms noise in the map should integrate down with the square root of the integration time. That is, the longer you integrate the "deeper" the map will be. Since SCUBA-2 will be a DC-coupled system any excess noise from the detectors or electronics, not removed by dark frames, may cause a residual "floor" or deterioration in the rms noise. Since a "confusion-limited" map will be obtained in about 2 hours at 850μm, it should be a requirement that the noise integrates down for *at least* this time period.

5.3 STARE mode

The most simple observing mode to visualise is a "point-and-shoot" mode, in which SCUBA-2 will "stare" at an 8 × 8 arcmin area of sky for a specified period of time. In this mode the map size is fixed to be the field-of-view on the sky. There are two complications to contend with for STARE mode. The first is how to deal with the 450μm undersampled array. The second is to design strategies that will allow the sub-array gap and any bad pixels (or columns of bad pixels) to be overcome. Both these complications will be addressed by adopting a micro-step technique using the SMU (similar to SCUBA). A possible scheme to contend with the sub-array gaps is illustrated in Figure 3.

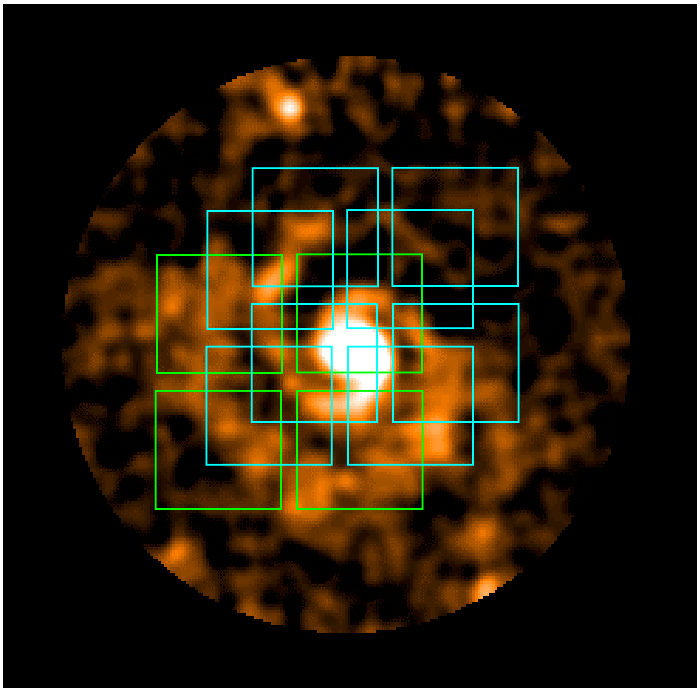

Figure 3: Possible micro-step pattern to contend with sub-array gaps.

The most optimum micro-step pattern still needs to be defined. However, since the 450um array is only a factor of 2 undersampled it is likely that the SCUBA-2 micro-step will be less complex, and involve fewer movements, than the one currently used by SCUBA. The only complicated for this may arise if there are significant numbers of bad pixels or bad columns of pixels on particular sub-arrays.

5.4 DREAM mode

In addition to the complications of residual 1/f pedestal, the brightness of the atmosphere with respect to the astronomical source, means that STARE mode requires a highly accurate flat-field (see "The SCUBA-2 Flat-Field Problem" ref: SC2/ANA/S100/43). The SCUBA-2 pixels will all have slightly different sensitivities. To ensure the astronomical images reflect real source structure these pixel to pixel variations in sensitivity have to be calibrated out. The accuracy required for the flat-field depends on observing mode and integration time but is most severe for a stare-mode (estimated to be 1 part in 10^7 for a one-hour observation). There are also potentially several factors that can cause the flat-field to vary. These include drifts in the electronics (must be made as common mode as possible), 1/f noise in the detectors or SQUIDs, variations in the detector responses as a function of background power (i.e. caused by relative changes in the bias setting). Hence, any flat-field changes will need to be monitored and corrected in real time (most likely using the cold shutter). However, the accuracy required may still not be achievable in practice for ultra-deep (or even reasonably shallow) observations. Alternative methods of "staring" are being considered, including a mode based on the DREAM observing strategy, developed for SCUBA (but never implemented due to the high sensitivity of the SCUBA bolometers to vibration from the secondary mirror unit). DREAM avoids the flat-fielding problem by using each bolometer to make a mini-map overlapped with its neighbours and then combining the result.

The initial design for the DREAM jiggle pattern is a star-shaped path with eight vertices. Figure 4 shows this as a pattern for a single bolometer on the 850μm array. Data taking occurs throughout the pattern, and the measured values are used to calculate interpolated values for the target sky positions (see "DREAM observing with SCUBA-2" ref:).

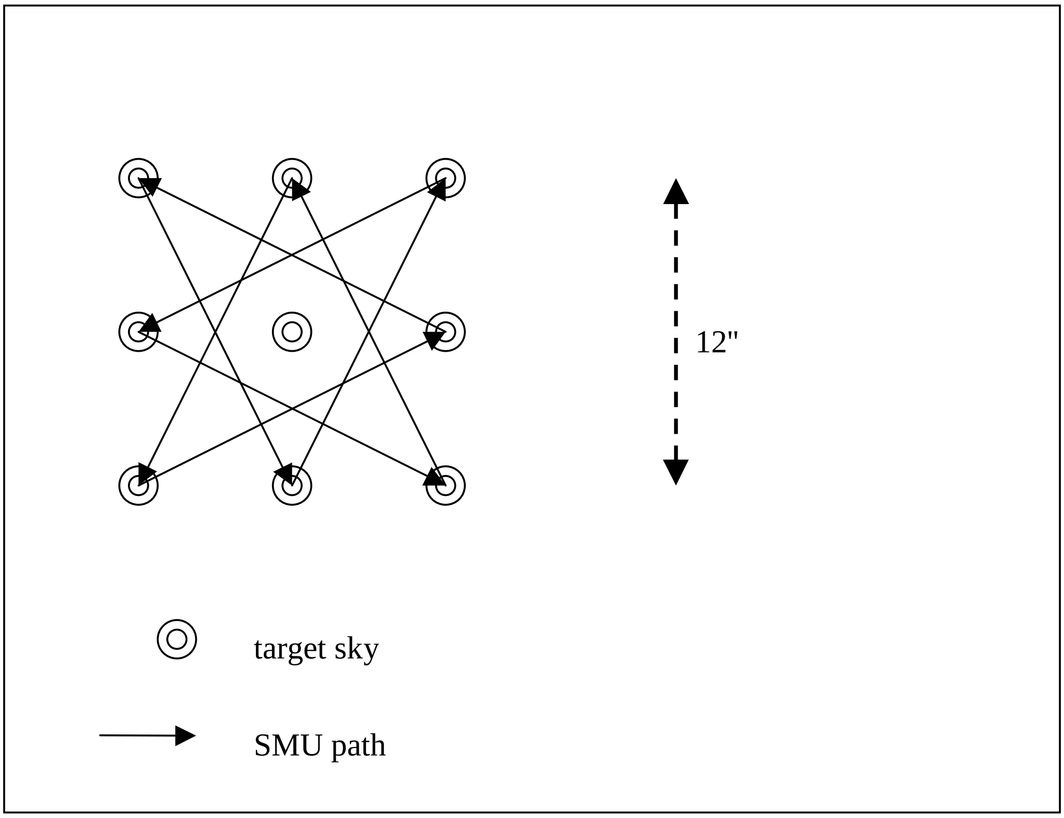

Figure 4: Possible DREAM pattern for a single SCUBA-2 pixel at 850μm.

5.5 SCAN (survey) mode

One of the major SCUBA-2 scientific goals is to conduct unprecedented wide-field surveys of the sky. Whilst it will be possible to mosaic stare or DREAM images together to form large-scale maps, the most efficient way of conducting large-scale surveys will be to scan the telescope very quickly across a source in an (overlapping) raster pattern. This is applicable to at least "shallow" surveys to identify sources of interest and/or to produce an "atlas" of interesting regions. The detector speed of response and the ability of the telescope to maintain astrometric information within the confines of the observation will determine the fastest speed. Scan speeds as high as 600 arcsecs/sec are likely. Scanning has much lower requirements on the flat-field accuracy and stability since the background will be removed by fitting a baseline to the raw data from each pixel. A 2 minute scan, at 600 arcsecs per second, and assuming no overheads would cover a strip of 20 degrees × 8 arcminutes. Shallow all-sky surveys could, in principle, be completed in just a few hours.

There is likely to be a subtle trade-off between scanning slowly (say, at a similar to SCUBA – 24 arcsecs/secs) or scanning very quickly (say, up to 600 arcsecs/sec). The trade-off is whether we should scan fast and cover a region a multiple number of times, or scan slow and spend more time per spatial point. Maintaining image registration and astrometry are also important here. There may also be issues associated in how the background is subtracted. The undersampled 450μm array makes scanning more complicated. Ideally, scanning should be along a line of azimuth (i.e. same airmass) to make atmospheric attenuation corrections simpler (and, in principle, more accurate). Figure 5 illustrates a possible scan pattern to cope with the 450μm undersampled array.

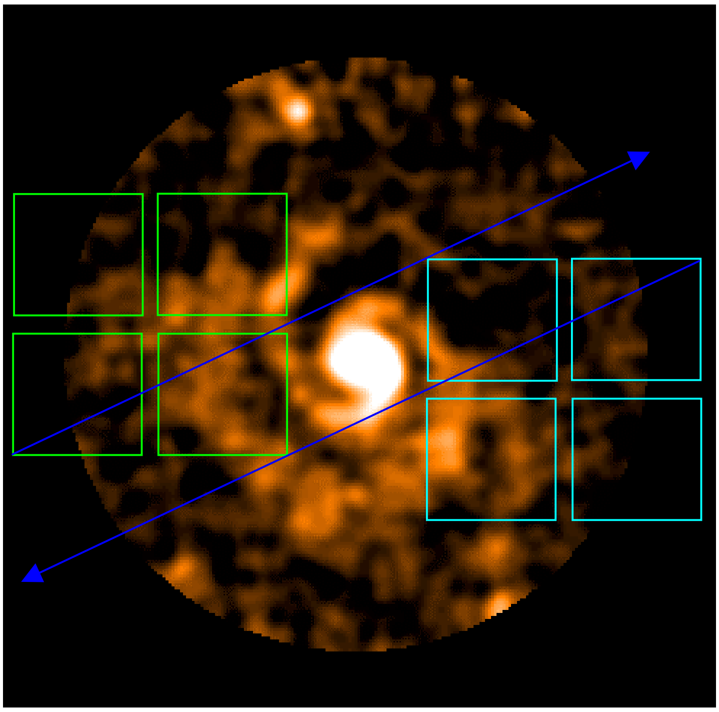

Figure 5: Illustration of overlapping scans at 26.6 degrees to contend with undersampled 450μm array.

6. Telescope actions

In carrying out the observing strategies described in section 5, it will be necessary to implement a number of telescope actions. These are discussed in this section.

6.1 Micro-stepping

Since the SCUBA-2 450μm array will instantaneously undersample the sky it will be necessary for STARE mode to fill in the gaps by using a small micro-step or jiggle (similar to that carried out with SCUBA). This will also compensate for the one-pixel gap between sub-arrays. Imaging mode will compensate for bad pixels (and/or rows/columns of dead pixels) and seams between the sub-arrays. If there are noisy pixels or bad columns of pixels then a more complicated micro-step may be necessary. If long integrations are needed sky rotation could fill in these gaps. The step will be done by the SMU, which is much quicker than moving the telescope. The size of the step may be dependent (limited) on edge-of-field aberrations induced by tilting the secondary mirror.

6.2 Mosaicing

It will be possible to mosaic individual SCUBA-2 frames together similar to an optical CCD camera or IR array. SCUBA has also frequently been used in this mode – i.e. coadding, spatially offset jiggle maps. The main scientific driver for this mode might be to follow a previously unknown extension of dust emission (e.g. an edge-on galaxy, or a ridge of sequential star formation). An obvious issue is whether mosaicing stare-maps or scanning is the most appropriate mode for objects that are extended by, say, a few fields-of-view. In mosaicing maps the challenge is likely to be in subtracting the sky background level in such a way that when the exposures are co-added the final image does not contain "seams".

6.3 DREAM patterns

Micro-step (or "jiggle") patterns with SCUBA are performed with the versatile secondary mirror unit (SMU). Offsets are generated by stepping through a table of 1024 (X,Y) positions, with each complete cycle through the table taking 1.024 seconds (i.e. 1 msec per position). This underlying implementation is hidden inside the computer running the OS/9 system. The command interface to the SMU runs on the supervising VMS machine and operates in terms of chop specifications, jiggle patterns and co-ordinate systems. In the near future SMU system will be revised to interact with the Real-Time Sequencer, and is expected to behave as part of the Telescope Control System, which is driven by the standard set of JCMT commands (SETUP_SEQUENCE, etc.) plus information in XML files.

The initial design for the jiggle pattern is a star-shaped path with eight vertices (see Figure 4). Data taking occurs throughout the pattern, and the measured values are used to calculate interpolated values for the target sky positions. In this pattern each of the eight straight sections is 13.4 arcsec long. If the pattern is completed twice in 1.024 seconds, then 64msec is spent on each straight section. If we assume that the velocity profile along the straight section might approximate a sinusoid, then the maximum velocity is then 0.32 arcsec/msec. The real system might have a steeper velocity profile, leading to a larger maximum velocity, but this number gives us a working estimate.

As discussed in SC2/ANA/S100/39, for the revised SMU to support the SCUBA-2 DREAM mode there are three requirements:

- synchronisation of SCUBA-2 data acquisition with SMU motion to 0.05 msec
- ability to specify the DREAM pattern in Nasmyth co-ordinates
- ability to download the pattern into the SMU

6.4 Focussing

Focussing will most likely be carried out in a similar way to that adopted by SCUBA. However, we will simply carry out fully-sampled maps for a number of SMU offset positions, with the peak being fitted by a parabola and passed back to the TCS for updating. One refinement is that we could slow scan the SMU (say, 0.1 mm per second) and continuously integrate.

7. Quality control

It is necessary to monitor a number of quality control (QC) parameters at the telescope during observations. This has always been the case, but is likely to be even more critical for SCUBA-2 since it will spend large fractions of time carrying out surveys. That is, we need to ensure uniform coverage and quality of the resulting images. The following tables list the parameters to be monitored for data quality control. The tables are split into science and instrument parameters.

Quality control parameter	Measured from	Calculated from	Comment
Atmospheric transmission	Line of sight radiometer; sky-dip	Three-load calibration	Radiometer preferred
Seeing	SMA "seeing" monitor; Possibly from shift-and add techniques	Extrapolated to 15-m baseline	
Image quality	Beam map	Main and error beam relative power	
Background brightness	Each frame	DC level across each frame	
Photometric accuracy	Calibration observation	Flux of standard source; repeatability of measurements	Absolute and relative levels

Table 2: Scientific quality control parameters.

Quality control parameter	Measured from	Calculated from	Comment
Bad pixels	Dark frame	Dark frame image to reveal "hot-pixels"	
Flat-field	Flat-field source	Spline-fit to data points	
Optimum closed-loop read out mode	Pixel and SQUID bias; heater level and feedback to SQUIDs		See: SC2/ANA/S100/31
Cryostat temperatures	Temperature sensors	Direct measurement	
Cryostat pressures	Pressure gauges	Direct measurement	

Table 3: Instrument quality control parameters

8. Calibration observations

In this section we describe the calibration observations which will be necessary for SCUBA-2. These are considered in the order that they are likely to be applied to the data.

8.1 Extinction correction

Sky-dips are measurements of the sky temperature as a function of airmass and are used to estimate the zenith sky opacity (and so apply to astronomical data a correction for the atmospheric extinction). SCUBA routinely carries out skydips in a raster mode between 15 and 80 degree elevation. It is not yet know whether SCUBA-2 will be able to carry out raster sky-dips, as the pixel response as a function of background must be corrected by the heaters in real-time.

It may be possible that the elevation gradient across the array, or local small elevation change skydips, can give an estimate of the relative change in sky opacity. Monitoring the DC level of the array after a skydip will allow local extinction corrections to be made. Alternatively, a separate radiometer can be used to continously monitor the water vapour level along the line-of-sight. If this is the case for SCUBA-2 then provision for reading this data into the image data stream is needed.

8.2 Flat-field

The SCUBA-2 pixels will all have slightly different sensitivities, and so images must be flat-fielded to ensure they reflect real source structure and not pixel-to-pixel variations in sensitivity. The accuracy required for the flat-field will depend on the observing mode and integration time, but the for the most extreme case is estimated of order 1 part in 10^7 for the STARE-observing mode (for a typical deep integration of a few hours). Hence, it will be necessary to integrate for several hours to obtain the accuracy required. It is envisaged that the instrument could stare at a constant temperature source, placed at a pupil image, during periods when SCUBA-2 is not being used for astronomy (e.g. during daytime).

8.3 Flux calibration

For flux calibration it will still be necessary to observe primary and secondary flux standards, as is the case for SCUBA. However, the speed of mapping and sensitivity of SCUBA-2 should allow new, fainter standards to be used (e.g. AGB stars, protoplanetary nebulae etc). SCUBA-2 will be able to observe both primary calibrators (Mars and Uranus) without fear of detector saturation.

8.4 Refraction ("seeing") compensation

Water vapour fluctuations above the telescope cause transmission, emission and refraction variations. By correlating the observed sky gradient across the array with pointing shifts it may be possible to correct individual frames for the effects of refraction before co-addition. This has not yet been modelled.

9. Data analysis and archiving

Once SCUBA-2 data has been acquired in either imaging or scan mode, a suite of software will then process the data it in a similar manner to SCUBA or IR arrays.

9.1 Data analysis

Each observing mode will have its own set of data reduction recipes. Within these recipes there will be some "tasks", such as extinction correction, which will be common to more than one mode.

It is likely that the following basic recipes will exist for SCUBA-2:

Recipe	Description
SCUBA2-STARE	STARE observing mode
SCUBA2-DREAM	For DREAM imaging
SCUBA2-SCAN	Scan map (raster) observing
SCUBA2-POINT	Pointing
SCUBA2-FOCUS	Focus and align
SCUBA2-SKYDIP	Skydip
SCUBA2-FLATFIELD	Flatfield measurements
SCUBA2-DARK	Dark-frame measurements

Table 4: SCUBA-2 top-level observing mode recipes

In addition, there may be a number of recipes specifically designed for engineering characterisation.

9.2 Quick Look

The purpose of Quick Look (QL) is to provide the observer with a prompt assessment of the data quality. For example, QL will address issues such as verifying that the instrument is working properly, and whether the sky is stable for the particular observation being attempted. Based on this information decisions can then be made as to what should happen next.

The basic operation of the Quick-Look Display is that recently-obtained data are processed to a sufficient level to generate a reasonable image which can then be piped onto the display so that it updates automatically as new images arrive. Various aspects of the display are under the observer's interactive control (e.g. scaling, zooming, areas of interest, colour selection). The software possibilities for QL include GAIA (currently used at UKIRT as a display tool) or the Qt Linux graphics system (to be used by ACSIS). The SCUBA-2 choice of display tool will be negotiated with JAC.

The QL processing software has to receive partially-processed data from the array of eight SCUBA-2 PCs which perform raw data collection. This partially-processed data consists of pixel values in Nasmyth coordinates, the precise form depending upon the observing mode (typically DREAM or SCAN). The QL software has to reconstruct and combine the image in (RA,Dec) coordinates, and then send it to the QL Display. This processing might involve simplified versions of the algorithms used in the pipeline.

The level of operations for QL still needs to be finalised. For example, for SCAN it is likely that the QL computer will perform tasks such as subtracting sky baselines and rebinning data frames into RA/dec co-ordinates, but not much more. It is anticipated that this will be done on a per-scan (SCAN) or per-exposure (STARE, DREAM) basis. The data is not calibrated, but it should be possible to co-add scans or exposures over a certain period of time (to be confirmed). No other corrections (e.g. any sophisticated refraction compensations) will be applied at this stage.

9.3 Pipeline processing

The pipeline will be implemented following the ORAC-DR scheme, which is already in use at UKIRT and JCMT for a variety of instruments (including SCUBA). What this means is that the data processing is coordinated by Perl scripts, with a script being provided to match each observing mode. The scripts operate by activating data processing applications and providing them with parameters (typically including the names of input and output data files). The scripts have to receive back status information and (where necessary) values from the applications. The applications have to be able to issue error reports that are displayed and logged. ORAC-DR aims to reduce data to a point where its quality can be fully assessed. In many circumstances it may even be sufficient to produce publication-quality results. It is anticipated that the pipeline will be running in real time at the telescope.

The present generation of data reduction applications (eg. SURF for SCUBA) consists of Starlink-style ADAM tasks written in FORTRAN-77. The assumption is that the SCUBA-2 applications will be written in a more modern programming language, and in addition the mechanisms for communicating between Perl and the applications will have to be specified and implemented. Similar considerations apply to the data format. The technicalities of this area have to be discussed with JAC (there are ongoing discussions concerning quality control and pipeline software for the UKIRT Wide Field Camera with Cambridge University which may be relevant here). It is also important to point out that some of the SURF applications may implement operations relevant to SCUBA-2. If this is the case, then a decision has to be taken as to whether the new SCUBA-2 applications need to run in the same pipeline with SURF, the alternative being to re-implement the applications in question.

It is important to distinguish between the data analysis software package and the pipeline. The pipeline is a reduction "black box" that knows the incoming data types (by their headers) and transparently applies a reduction recipe to them. The pipeline can be run many times, as the observer requires, in lots of different configurations. Figure 6 shows the steps that happen during pipeline processing using ORAD-DR. For convenience the following terms are defined:

pipeline

Software that runs without external intervention, taking raw data on one end and producing reduced data in the other.

data-driven

Software that does nothing until data arrives, and then looks to the data and not the user for data reduction information.

recipe

A file containing a list of individual data reduction steps.

primitive

A file containing code performing a meaningful data reduction step

engine

An external package (e.g. a Starlink task) that performs a certain algorithmic step (e.g. addition).

ORAC-DR is entirely controlled by the command line options entered at when the pipeline is initiated. From that point on, the system either takes its reduction recipe instructions from the file headers (this is the default) or uses a hardwired recipe given on the command line itself. The recipe is, in fact, the only allowed parameter on the command line - all the rest are options. Once ORAC-DR is started, there is no further control over it. It is anticipated that ORAC will be sophisticated enough to check, for example, that calibration frames exist.

As discussed in section 9.1 data reduction recipes will exist for processing data from the standard SCUBA-2 observing modes. This should not limit the flexibility of any given recipe since they are designed to work for any data from that mode. Occasionally it is necessary to modify recipes (e.g. to blank out bad pixels or columns of bad pixels, or to change the output pixel scale for rebinning).

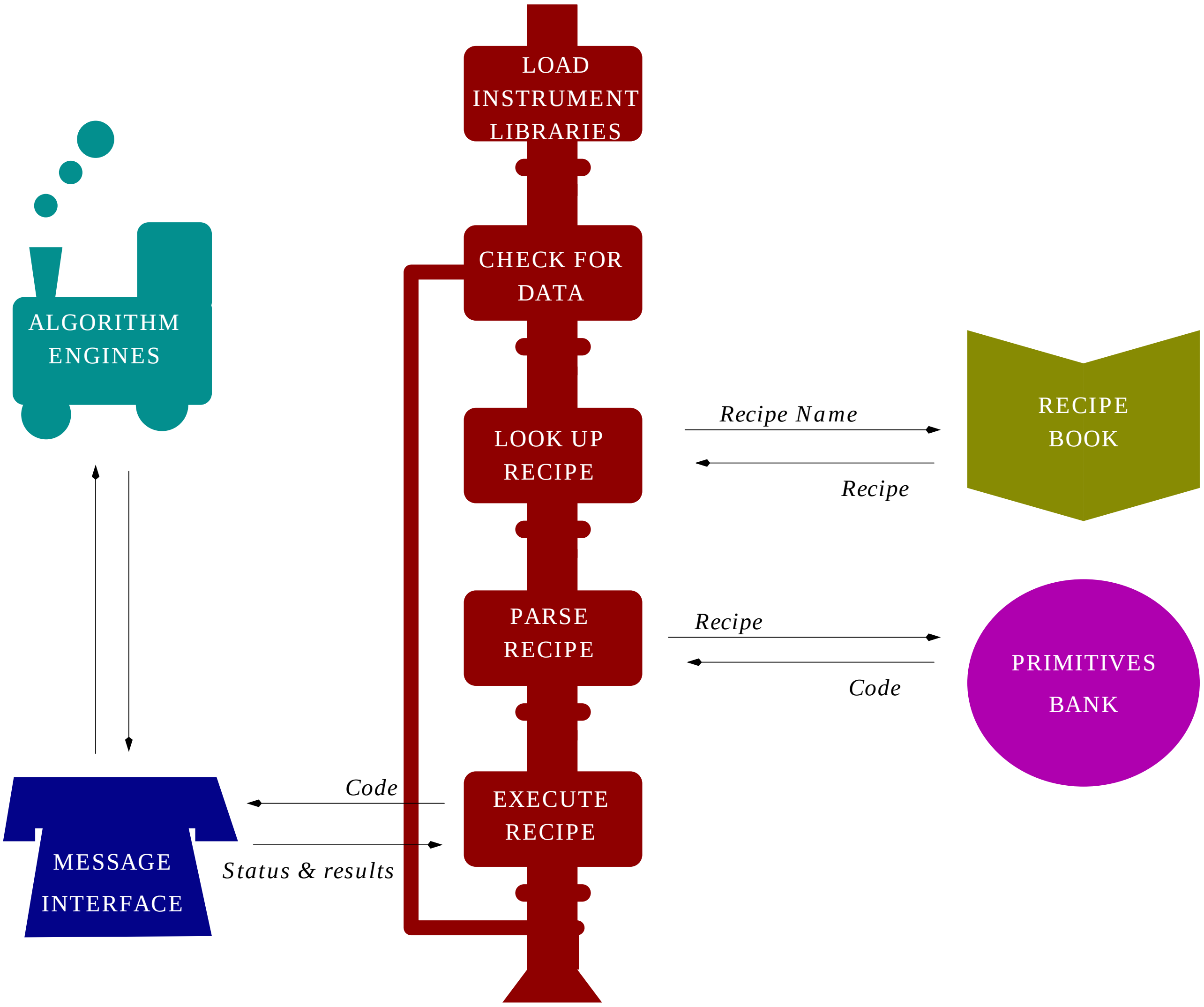

Figure 6: Outline of steps during pipeline processing (from SUN230)

9.4 Archiving

Software has to be present to transfer data from the end of the pipeline to the data archive. In addition, the information present and its structure have to be defined in such a way as to make the archived data usable by researchers. This has an impact on the specification of the header information coming out of the pipeline, and so affects both header information generated within the pipeline and real-time information forwarded through the pipeline.